DETAILED DESCRIPTION OF THE INVENTION

Figures 1 and 2 of the drawings disclose an oil well or borehole 10 within which there is supported a tubing string 12 telescopingly received within a casing 14. Casing 14 is located within the formed borehole 10 that extends from wellhead 18 at the surface 11 of the earth, through a formation or payzone F, and continues on downhole at 14, or might instead curve at 14' into another payzone as noted at F2, such as is achieved with directional drilling. Casing 14 is perforated in the usual manner at P1 or P2.

A wire line tool string 15 has been run into tubing string 12 contained within casing 14 of borehole 10 on an E-line 17, a slick line or wire rope having an electrical conductor therein. Sometime, the tool may be run into the borehole on the end of any suitable elongate member, such as a suitable conduit or elongate tendon such as a pipe, a sucker rod string, or most any logical support member suitable for the occasion.

Usually, a wire rope 17 having a suitable insulated electrical conductor therewithin, is used for supporting a tool string 15. A lifting rig 20 can take on any number of different forms and should include a weight indicator connected to determine tension of the wire rope or E-line 17 which is spooled onto a drum at 20 with the downhole end of E-line 17 terminating in a rope socket 19 at the up-hole end 21 of a sinker bar 22 of tool string 15. The insulated conductor is electrically connected to continue through a passageway formed in sinker bar 22, through a jar tool 16, made in accordance with the present invention, and to the lowermost apparatus 24 which is supported by the lower end 31 of jar tool 16, thereby providing transfer of electronic data signals downhole and uphole along E-line 17 that supports tool string 15.

Sometime borehole 10 is relatively straight, as seen in

10/757,254

Figure 2. Sometime a borehole is crooked, or is deliberately slanted as illustrated in Figure 1. Most boreholes are crooked and this increases the probability of a string of tools becoming stuck downhole in the borehole, as seen illustrated in Figure 1 at 118, for example.

The uphole end of the jar tool 16, as seen in Figure 2A, preferably terminates in a closure that takes on the form of a sub 30 presenting a box end 30' opposed to the downhole end 31, where various different apparatus, including instrument packages and the like, can be supported. The opposed ends 30, 31 are easily interfaced with other tools by standard subs in a manner that is known in this art.

Figure 3 discloses additional details of tool string 15 of Figure 1, comprising, commencing at the upper end of Figure 2, a wire line or E-line 17, a rope socket 19 attached at 21, to a sinker bar 22, the jar tool 16 of this invention, and an adaptor sub 31 which terminates in attached relation respective any desired tool or instrument package 24 that reasonably can be supported from the lower end 31 thereof.

Still looking at Figure 3, sinker bar 22 can be of any desired length, so long as its mass enables resetting jar tool 16 after a jarring action of the jar tool has taken place, thereby enabling multiple sequential jarring actions to be carried out, as will be more fully appreciated later on herein. At the top 30 of jar tool 16 and in underlying relationship respective sinker bar 22, it will be seen that the diagrammatical representation of the jar tool 16 of Figures 2 and 3 has been subdivided into the indicated Figures 2A through 2F, thereby enabling the details of each of these assembled Figures to be more fully disclosed on six different sheets of drawing, submitted herewith and forming part of this non-provisional patent application. It should be appreciated that an E-line 17 or equivalent, is connected to a conductor ex-

tending axially through sinker bar 22 into communication respective the uppermost end 30 of jar tool 16, and thereafter the electrical conductor extends axially through jar tool 16 into electrical contact respective the instrument package 24.

Figure 2A illustrates the preferred embodiment of the uphole marginal length of jar tool 16 in greater detail. An upwardly opening box end 30 forms the upper end of jar tool 16 and threadedly engages the lower end of the before mentioned sinker bar 22 by using a suitable interfacing sub as may be necessary. An axial passageway 32 extends longitudinally through the entire jar tool 16, as well as through the sinker bar 22. Hence numeral 32 indicates the initial part of the annular passageway formed between connector 35 and the connector 42.

The upper terminal end of a hollow protective tubing 33 is anchored or removably received in close tolerance relationship within connector 142 in order to sealingly accommodate the electrically insulated conductor 34 suitably protected therewithin for providing a source of power to any desired instrument package 24 attached at the lowermost end 31 of jar tool 16 for data transmission from below jar tool 16 uphole to the surface 11, as previously noted.

Cylindrical insulator 35 provides for attachment of the conductor 34 at terminal end 36 of through conductor 34. Connectors 37, 39 are male and female connectors that are telescopingly fitted together and mounted within the enlarged portion 38 of passageway 32 to facilitate assembly of the various threadedly connected tool components of this invention. Seal means (not shown) are suitably seated within the seal grooves 40 and preferably are high temperature o-rings. Chamber 141 formed within the bell shaped member 41 isolates connector 39 therewithin to enable access to connector 39 and to continue through chamber 241 into the next adjacent chamber 51 of Figure 2C.

In Figure 2B, axial passageway 32 that accommodates tube 33 continues down through the central axis of jar tool 16 where it is concentrically arranged respective to a larger annular chamber formed between the outside diameter of protective tubing 33 and the inside diameter of the main housing 49.

Main housing 49 includes a marginal length of the hollow main shaft member 43 reciprocatingly received therein. Looking again now to Figure 2A together with Figure 2B, the sealed connection device 142 in chamber 141 seals the working chamber or annulus 146 respective the hollow main shaft 43. Any number of different seal devices can be used, this example being for teaching purposes in order to enable full comprehension of the disclosure.

In Figure 2B and 2C, conductor 34, tube 33 and axial passageway 32 continue axially through jar tool 16 in order to protect insulated electrical conductor 34 which is coextensive therewith. The illustrated through conductor 34 is protected by suitable insulation which further is protected by the before mentioned through tubing 33.

The before mentioned hollow main shaft member 43 is threadedly engaged by adjustment nut 44 which is locked thereto by adjustable fastener means as indicated by numeral 45. The lower end of adjustment nut 44 abuttingly engages the uphole end of the illustrated annular Bellville washer stack 46 having a strong spring or biasing action. Bellville washer stack 46 terminates with the downhole end thereof abuttingly engaging the uphole end of a powerful, fully compressible spring device 47, with there being a spacer or separator 48, such as a washer, placed therebetween and separating annulus 149 into stored energy chambers 146, 147.

Main housing 49 f Figures 2A, 2B, and 2C is seen to be sectioned into multiple lengths to facilitate assembly, and are connected together by means of a sub 50 (Figure 2C) through which the before mentioned main shaft member 43 (Figures 2B and 2C)

reciprocatingly extends. Main shaft 43 continues into threaded engagement with respect to an internal shaft connector 51, which also serves as a guide that is slidably received within main housing 149, which is considered a continuation of housing 49.

The tube 33, positioned within axial passageway 32, continues through hollow main shaft member 43 and includes insulated conductor 34 therein, all of which continues through main housing 49, 149 as shown in Figures 2A, 2B, 2C and 2D. Note that the upper housing 49, 149 are positioned above the lost motion coupling 68 of Figure 2D while the lower housing 249 of figure 2E is therebelow, as will be more fully discussed later on herein. The housing 49 as seen in Figure 2C, is connected to housing 149 by means of a sub 50, having opposed faces 150,250 through which internal threaded bores are formed for threadedly receiving the before mentioned hollow shaft member 43 into threaded engagement with respect to internal slidable connector 51.

As shown in Figure 2C, axial passageway 32 continues on through main housing 49, 149, sub 50, internal connector 51, and axially through the lower spring chamber 154 where it is connected to the releasable latch apparatus 56, 57, 156 disclosed in Figure 2C.

Adjustment nut 52, as best seen in Figure 2C, threadedly engages the marginal threaded end 43' of the lower end 43'' of hollow main shaft part 43, while the lower end thereof also threadedly engages internal connector 51 as noted at 151 in Figure 2C. Internal main shaft connector 51 threadedly engages the uphole end 243' of releasing member 53' and is a continuation of the before mentioned main shaft part 43. It can be seen that sub 51 is slidably received in a reciprocating manner within the interior of main housing 149.

In Figures 2C and 2D, the upper end of power spring 54 abuttingly engages the lower end of sub 51 as noted by numeral 151

in Figure 2C, and is contained within the illustrated annular spring chamber 55. As seen in Figures 2C and 2D, the lower end of spring 54 abuttingly engages the upper enlarged end 156 of sleeve 56, while the opposed circumferentially extending end 356 of sleeve 56 bears against internal shoulder 59 of the main housing. Sleeve 56 can be moved axially within its chamber 154 between spring 54 and shoulder 59 responsive to movement of main shaft 43. The sleeve has a counterbore forming an interior shoulder at 156 which abuttingly engages a complimentary shoulder 157 formed on enlargement 57 of latch member 60 that is formed at the lower end of main shaft 43. Hence, lower terminal end 356 of sleeve 56 abuttingly engages shoulder 59 formed internally at 149 on main housing 49. Enlargement 60, which is part of latch apparatus 60, 61 is a continuation of main shaft 43 and forms the male latch part 143, 156, 57, the skirt 356, and the enlargement 60 at the lower terminal end thereof. Male latch part 60, when forced into the interior of female latch member 61 of the latch device 60, 61, occurs responsive to downhole movement of the main housing which concurrently compresses the before mentioned three spaced biasing or spring members seen in stored energy chambers 149, 147 and 55 when the tool is reset into the standby configuration, ready to deliver a jarring action. At terminal end 63 of enlargement 60 is a passageway 132 that is a continuation of passageway 32 that slidably receives through tube 32 therewithin, remembering that the tube is anchored to the before mentioned seal 142, and thereby enables relative movement between main shaft 43 and the through tube 32 while through tube 32 forms a protective housing for conductor 34. It should be noted at this time that the conductor 34 does not significiently telescope respective to the telecoping tube 32.

As further seen in Figures 2D and 2E, releasable latch apparatus 60, 61 includes female member 61 made of a multiplicity

of radially arranged, circumferentially extending, longitudinally disposed resilient fingers 62 which enlarge at 64 to threadedly engage elongated lower main shaft member 65 while the lower end of main housing 149 threadedly engages a bottom closure member in the form of a sub 66 (see Figure 2D). Sub 66 includes guide pin 168' received within a key way or spline 168 formed on lost motion coupling 68 to maintain closure member or sub 66 of lower housing 249 and sub 66 of upper housing 149 aligned respective to one another as the confronting faces 70, 71 of the spaced jar tool subs 66, 69 are moved towards and away from one another, but always remain spaced apart from one another a slight amount after the tool is scoped together for reset, and assumes the illustrated configuration of Figures 2D, 2E following a jarring action and prior to reset. The spaced distance between subs 66, 69 is the measure of one stroke.

In Figures 2E and 2F, sub 69 is seen to include a radially formed longitudinal counterbore that forms blind passageway 73 within which a guide member 72 is reciprocatingly received such that upper terminal end 74 thereof is always spaced from the blind end of the counterbore that forms radial passageway 73.

As particularly illustrated in Figure 2E, one end of guide member 73 is affixed to a pressure differential traveling piston 174. The piston has seal grooves 75 suitably formed thereon, thereby isolating chambers 76, 77 from one another as fluid enters and leaves through the ports 78, thereby isolating chamber 77 from well fluids while subjecting chamber 76, to the hydrostatic head of the well fluids.

Chamber 77 is filled with a non-compressible, non-conducting mineral oil to reduce the likelihood of well fluids contaminating the electronic components of the jar tool.

Accordingly, piston 74 moves in low friction relationship respective the interior of main housing 249 and the exterior sur-

7

face of through tube 32 through which conductor 34 extends, thereby avoiding contamination of the interior of tube 32.

Conductor 34, as shown in Figure 2E, is formed into a looped or serpentine configuration as indicated at numeral 80, allowing the feed through wire tube 32 to move along the central axis of the jar tool while always having slack at 80 in order to accommodate undue wire tension during reciprocation of tube 32 within main shaft member 43, noting that tube 32 reciprocates concurrently respective sub 49 seen at the anchor seal at the upper end of the jar tool. Enlargement 81 forms a stop member on the interior of main housing 249 for limiting travel of piston 74 in the unlikely event of leakage of well fluid thereinto.

In Figure 2F, the lowermost end of conductor 34 is received by electrical connector 82 and continues through lowermost sub 83 that forms the lower terminal end of jar tool 16 and thereby enables jar tool 16 to be connected to any desired apparatus at threaded end 283. As further seen in Figure 2F, a connector 84 is received within enlarged axial counterbore 85 for conducting current flow at 86 to and from the illustrated instrument package 24. Seals 87 and 88 prevent entry of fluid into the lower end of jar tool 16.

Figure 4 illustrates a hypothetical analyses of the action of jar tool 16 during one jar action. Curve 4 is a plot of the wire line tension commencing with the tool static, hanging free within the in borehole. Curves 1-3 illustrate the upthrust realized from each of the three spring or stored energy chambers. The remaining curve that reaches 1,000 pounds is the sum of curves 1-4.

Characteristics of curves 1-3 can be modified by various changes to the tool as set forth herein, and this, of course, results in a modification of the 1,000 pound curve. In actual practice, it is possible to develop approximately 3,000 pounds

9

upthrust with this embodiment of the invention.

IN OPERATION

In operation, the assembled jar tool 16 is adjusted or set to be actuated at a predetermined fraction of the maximum tensile strength of the E-line. For example, if the E-line breaking strength is 1,000 pounds, the operator may elect to adjust the release tension of the tool latch 61 to be triggered by an uphole force of 200-300 pounds, as read on a weight indicator. This is the force required for the E-line to trigger or pull the male end 60 from the female end 62 of the releasable latch member 60, 61. Resetting the tool for subsequent jar actions requires a downhole force applied to the upper end of the jar tool, similar to the releasing force, depending on the design of releasable latch member 60, 61. Hence, sinker bar 22 must be of a weight greater than the releasing value of latch 61 in order to be on the safe side. Those skilled in the art know to consider the entire weight of the E-line and tool string when viewing the weight indicator at the surface.

Adjusting nut 52 should be set by the shop technician who should make certain that latch means 61 is also adjusted into proper position respective sleeve 56, and reduced diameter passageway at 349, at this time by properly spacing out the component parts of the jar tool. Adjusting nut 44, located immediately adjacent the upper stored energy or spring chamber 146, is rotated or set for minor adjustments in the field. This action gains the desired releasing value of latch assembly 61 and is realized through trial and error while studying the situation using a suitable weight indicator for accuracy.

The adjustments of nut 44 pre-loads the three spring chambers of the upper spaced spring chambers which in turn places a continuous uphole force on male member 60 of releasable latch assembly 60, 61. Accordingly, this action commences a releasing action which is somewhat analogous to the action of the E-line as

the release tension force is applied.

The complex action of the jar tool is easily comprehended when it is appreciated that the operating mandrel or main shaft 43 extends from enlargement 43' located at the upper extremity thereof and extends through first spring chamber 146, through second spring chamber 147, through sub 50, adjustment nut 52, and operating chamber 152, where it is joined to the threaded internal connector 51, continues through the third and lowermost spring or energy storage chamber 154, and terminates as the illustrated male part 60 of releasable latch device 61. The main shaft 43 therefore can be forced to slide axially between the limits provided by opposed confronting faces 151, 252 and 250, 152 within chamber 350.

In Figure 2D, hammer 166 and anvil 165 are illustrated in the impact position.

Male release member 60 together with female latch member 61 are unique in that it cooperates with the third spring chamber 55 in several different manners. Note sleeve 56 is slidably received within the third spring chamber 154 and has an enlargement 156 thereon that abuttingly engages power spring 54 as well as the enlarged diameter part 349 that forms shoulders 59, 59' formed on an inner limited length of main upper housing 149. Also note enlarged member 57 on latch member 60 that is also part of the main shaft 43 and engages member 156 at shoulder 157. Further, sleeve 56 has a downhole end 58 that abuttingly engages shoulder 59 of outermost housing 249. The third spring 54 biases sleeve 56 down-hole while abutting internal slidable connector 51 to thereby provide part of the stored energy for contributing to the upthrust of main body 49 together with the other biasing means or stored energy devices of this disclosure. Hence, sleeve 56 is always biased or urged downhole against shoulder 59 by adjacent spring 54 as shown, except when main upper housing 149 moves downhole towards lower main housing 249 during reset. In order for connected

or engaged latch assembly 61 to telescope into smaller diameter chamber 260, the latch parts 60, 61 must be fully engaged while they are within the large diameter latch chamber 261, because the latch assembly 61 cannot be reset nor released once it is positioned within small diameter chamber 169, due to the relative diameters of the coacting members.

The latch 60 telescopes into chamber large diameter bore that forms chamber 261 where latch parts 60, 61 have ample room to expand into latched engagement, while they are within the large part 349 of the latch chamber. Hence the latch cannot be set nor released once it is positioned within small diameter bore 349 of chamber 260.

Those skilled in the art having digested this disclosure will appreciate that the lower main housing of the jar tool, when stuck or otherwise held stationary, while the upper box end 30 is forced downward respective thereto, the lost motion coupling 68 telescopes into closure member or sub 66, while the anvil 65 is reposition further towards the upper tool end as the main housing descends, thus moving the latch means and anvil uphole away from hammer 166 concurrently with the separation of faces 70, 71, respectively, of the confronting subs 66, 69 while at the same time moving enlargement or anvil 65 along with the female latch part 61 into the latched position, which occurs only in the large diameter latch chamber. Accordingly, confronting faces 70, 71 of the main chamber members are brought into proximity of one another, but preferably, they always remain slightly spaced apart.

At this time, main housing 49 connector sub 50 contacts nut 52, thereby forcing main shaft 43 downhole which compresses each spring associated with the three spring chambers 146, 147, 155 and latches members 60, 62 together.

During this movement, the male latch part 60 is telescopingly received within the resilient fingers 62 of the female member

of the latch device 61 as the female part 62 encapsulates the downwardly moving male part 60 of the latch device 61, 61. Simultaneously with this action, energy is stored within the three spring chambers.

In addition to the ability to preload the various springs by addition of spacers and the like, the adjustment means 44 near the upper end of the main shaft as well as the other adjustment means 52 located within chamber 53 between sub 50 and internal slidable connector 51 are adjusted to control the required tension in the E-line for triggering the release of latch 60, 61. It should be noted that the uphole enlarged terminal end of main shaft 43 is always spaced from anchor and seal means 42 as shown, to prevent impact therebetween. Further, nut 44, when torqued one turn (360 degrees) against spring device 46, preloads both the first and second spring devices with the equivalent of 50 pounds wireline tension, and consequently places an uphole force on male member 60 of the releasable latch device, thereby providing a means by which the tension in the E-line for releasing the latch device can be selected in the field.

When adjusting nut 52 is moved along threaded surface 53', the length of the jarring stroke is changed, while at the same time should the adjusting nut 52 be torqued against the downhole face of sub 50, this action will force male part 60 further into female part 61 of the latch device while pre-compressing the springs in all three stored energy chambers. Further, it should be noted that latch device 60, 61 can always be set into the latched position so long as the parts are properly spaced out to provide for the before mentioned adjustment.

In one embodiment of the invention, for example, the adjusting nut 44 increases the line tension 50 pounds for each full rotation of the nut.

4